TECHNICAL MEMORANDUM

FROM: Barbara Mosier, Emily Koehle, Alia Anderson, and Larry McGoogin, Toole Design Group (providing technical assistance on behalf of the Office of Intermodal Planning and Investment)

TO: Erin Yancy and Jakob zumFelde
The City of Harrisonburg, VA

SUBJECT: Harrisonburg Street Connectivity Evaluation and Road Diet Multimodal Evaluation, Task 3 Technical Memorandum – **Revised**

Feasibility of Road Reconfiguration on Three Corridors – Road Diet Multimodal Evaluation

DATE: Original July 6, 2022/**Revised and Resubmitted August 17, 2022**

NOTE: The opinions and conclusions expressed or implied in this report are those of the authors and are not necessarily those of the Office of Intermodal Planning and Investment (OIPI). OIPI does not endorse products or manufacturers. Any trade or manufacturers' names that appear herein are solely because they are considered essential to the object of the report.

Introduction

The purpose of this memo is to summarize the traffic operational analysis and design approach for the following potential roadway reconfiguration corridors in Harrisonburg, VA, shown on Figure 1:

- 1.46-mile segment of Garbers Church Road between Erickson Avenue and W Market Street (US 33)
- 1.50-mile segment of W Market Street (US 33) between Garbers Church Road and High Street (VA 42)
- 0.85-mile segment of E Market Street (US 33) between Mason Street and Vine Street

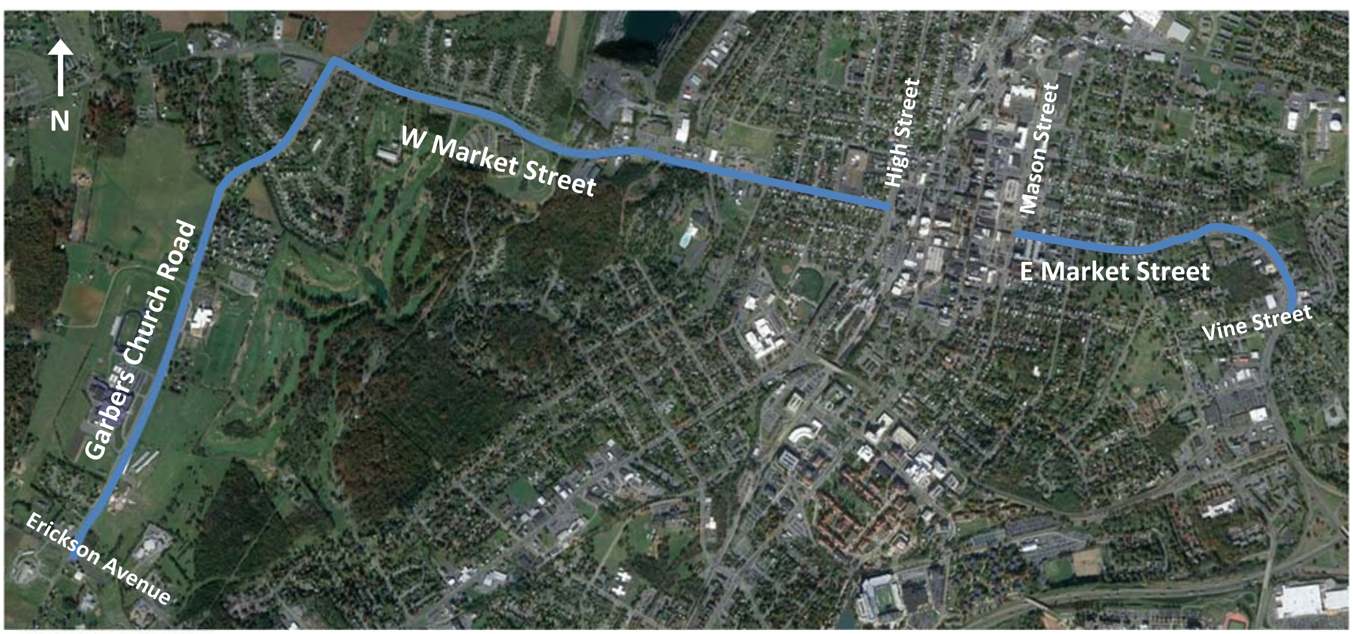

Figure 1: Study Corridors

This memo includes a summary of opportunities and constraints for roadway reconfiguration on the three corridors, a crash summary provided by the City, three alternative cross sections that were presented to the City, tradeoffs between each alternative, feasibility of roadway reallocation, and the selection of a preferred alternative.

A preliminary assessment of the average daily traffic volumes (ADT), compared to thresholds from the FHWA Road Diet Informational Guide, revealed that the study corridors are good candidates for road diets. According to the Guide, agencies should conduct intersection analyses and consider signal retiming in conjunction with implementation and conduct a corridor analysis, described in this memo.

The traffic operational analysis was conducted at 26 intersections across the three corridors using Synchro analysis and Highway Capacity Manual (HCM) methodologies to report vehicular delay, vehicular Level of Service (LOS), volume-to-capacity ratio (v/c), and 50th and 95th percentile queues, are presented for the AM and PM peak hours under future 2040 no build conditions and the preferred alternative with predicted 2040 traffic volumes (see page 22 for the definitions of these terms). This memo also includes a discussion of design details to advance the reconfiguration concepts into further design phases.

Opportunities and Constraints

Garbers Church Road, W Market Street, and E Market Street all consist of two travel lanes in each direction with turn lanes at several intersections along the corridors. The space encompassed by these travel lanes provide the opportunity to reconfigure one travel lane in each direction to serve other modes such as bicyclists, while maintaining at least one lane for motor vehicles.

Details on the geometry of the existing cross sections and traffic information including the average daily traffic (ADT) volume collected in April 2022, projected future 2040 volume based on a regional growth factor of 1% per year as provided by the City, and speed limits for each corridor are described in the tables and figures below. The specific ADT data collection locations are shown in Figure 2. Note: dimensions shown in the figures in this section are approximate and have been refined in the concept design based on GIS and aerial images.

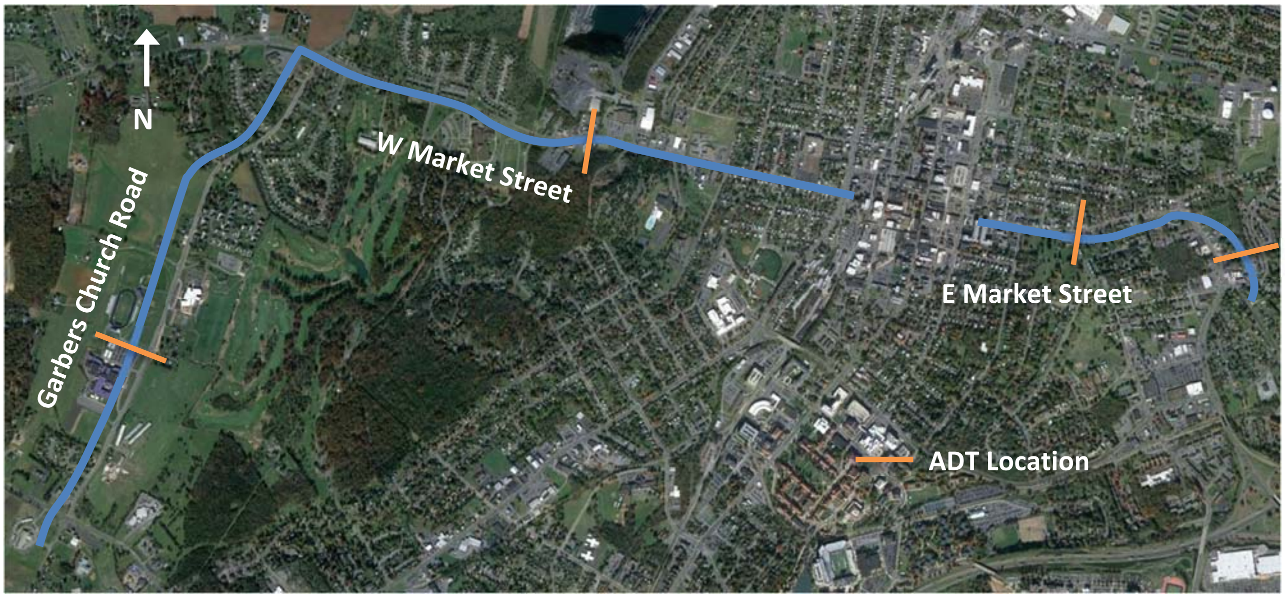

Figure 2: 2022 ADT Data Collection Locations

Garbers Church Road

Table 1: Garbers Church Road Corridor Details

Detail	Garbers Church Road
Width	• Approximately 48’ curb to curb, up to 60’ at intersections
Turn lanes	• Turn lanes in the vicinity of High School
Median	• No median
Sidewalks	• No sidewalks on either side south of Springside Drive • No sidewalk on east side between Springside Drive and High School north entrance
ADT	• 2022: 6,455 vpd between Harrisonburg High School and Bluestone Elementary • Projected 2040: 7,720 vpd
Speeds	• Speed Limit – 35 mph • 85th Percentile Speed – 40 mph at curve

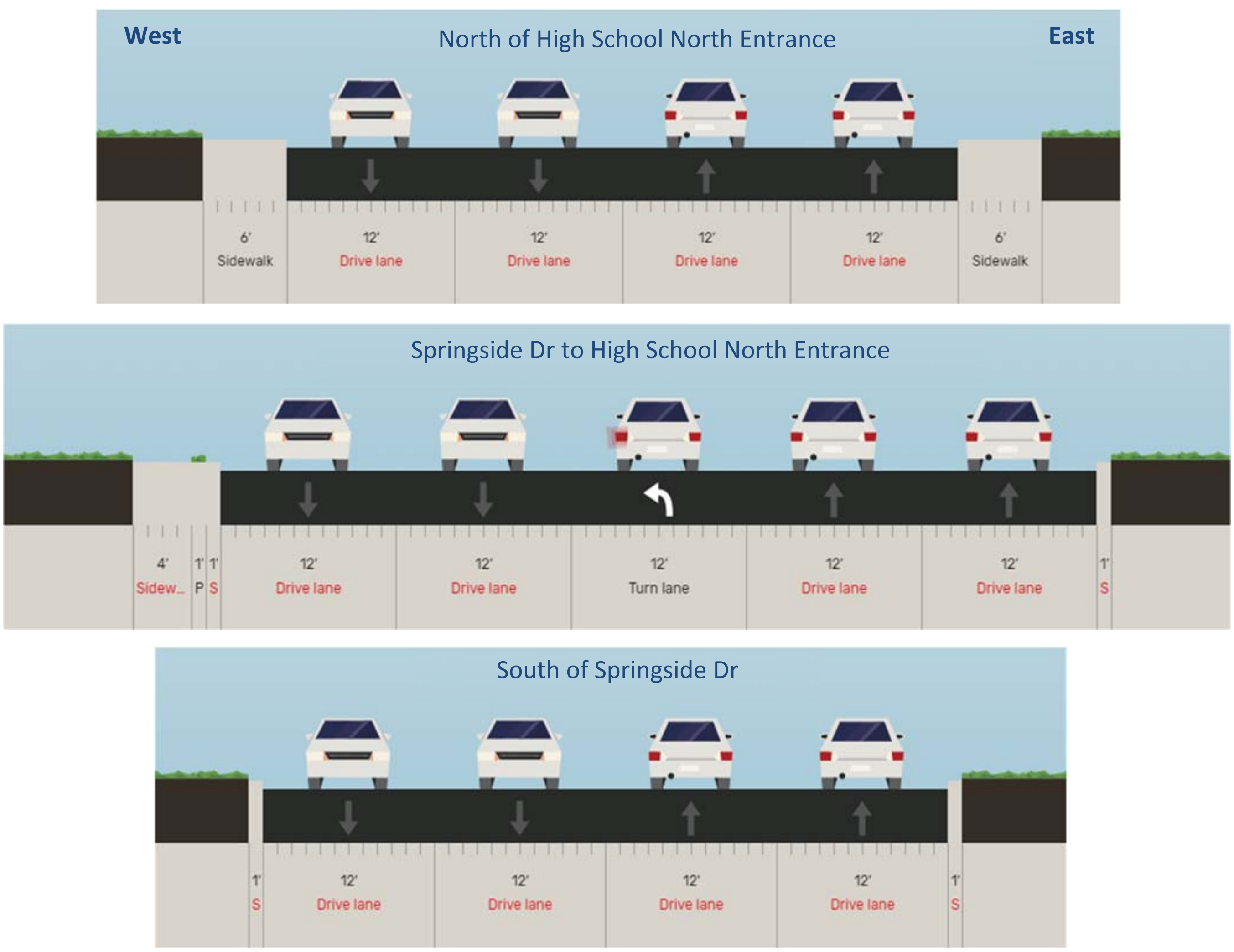

Figure 3: Garbers Church Road Cross Sections

Growth & Accessibility Planning
TECHNICAL ASSISTANCE PROGRAM

W Market Street

Table 2: W Market Street Corridor Details

Detail	W Market Street
Width	• Approximately 66’ curb to curb, up to 80’ at intersections
Turn lanes and Median	• West of car wash: Turn lanes at intersections, grass median • Car wash to Dogwood Dr: Two-way center left-turn lane (TWLTL) • East of Dogwood Dr: No turn lanes, no median
Sidewalks	• No sidewalk north side of street, west of car wash
ADT	• 2022: 12,050 vpd east of 7-Eleven • Projected 2040: 14,415 vpd
Speed Limit	• 35 mph

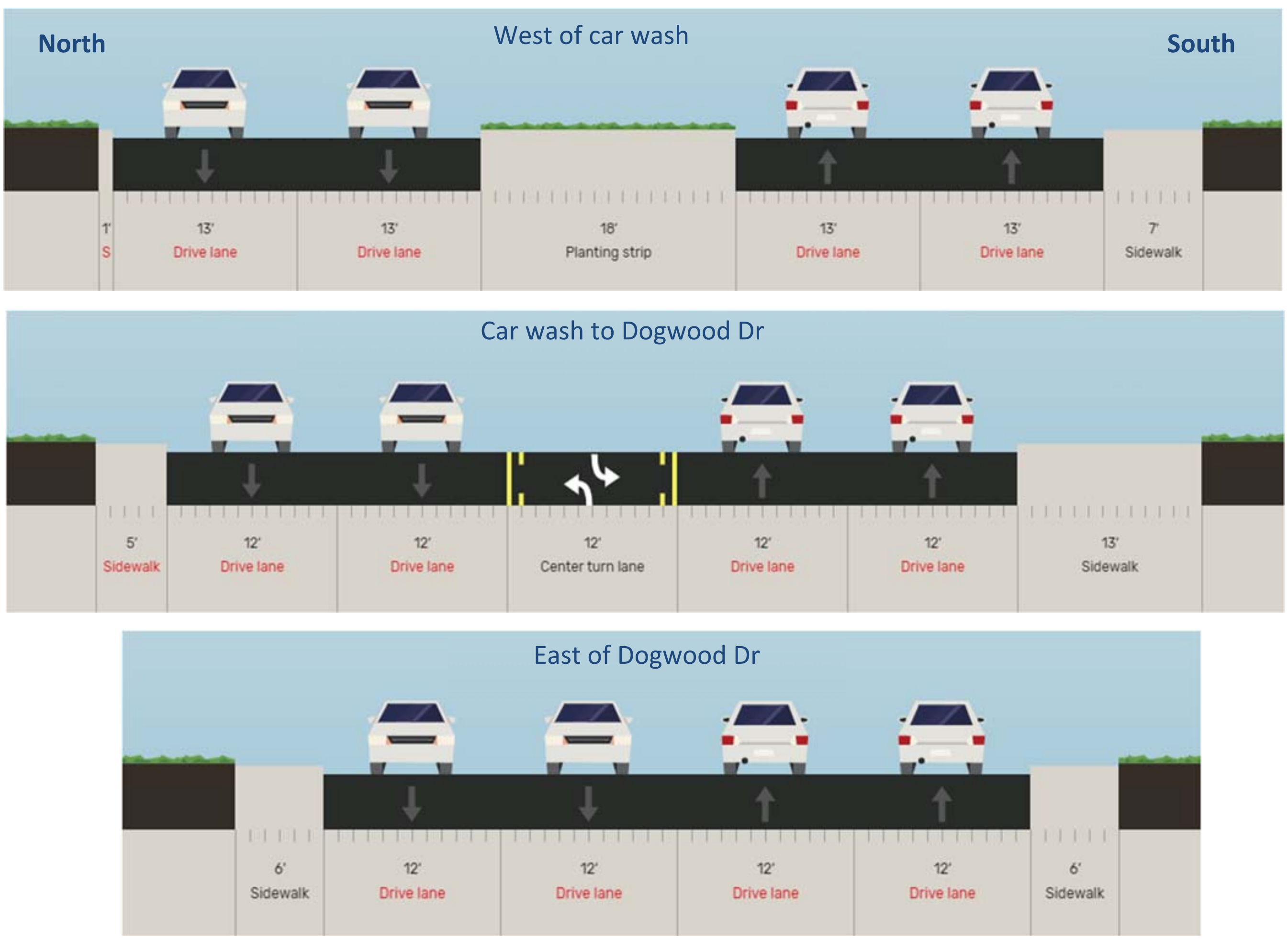

Figure 4: W Market Street Existing Cross Sections

E Market Street

Table 3: E Market Street Corridor Details

Detail	E Market Street
Width	• Approximately 48' curb to curb
Turn lanes	• Turn lanes at Old Furnace Rd and Hawkins St/Vine St
Median	• No median
Sidewalks	• Continuous sidewalks
ADT	• 2022: 16,516 vpd between Ott Street and Myrtle Street • 2022: 12,516 vpd between Old Furnace Road and Vine Street • Projected 2040: 19,755 vpd between Ott Street and Myrtle Street • Projected 2040: 14,970 vpd between Old Furnace Road and Vine Street
Speed Limit	• 35 mph

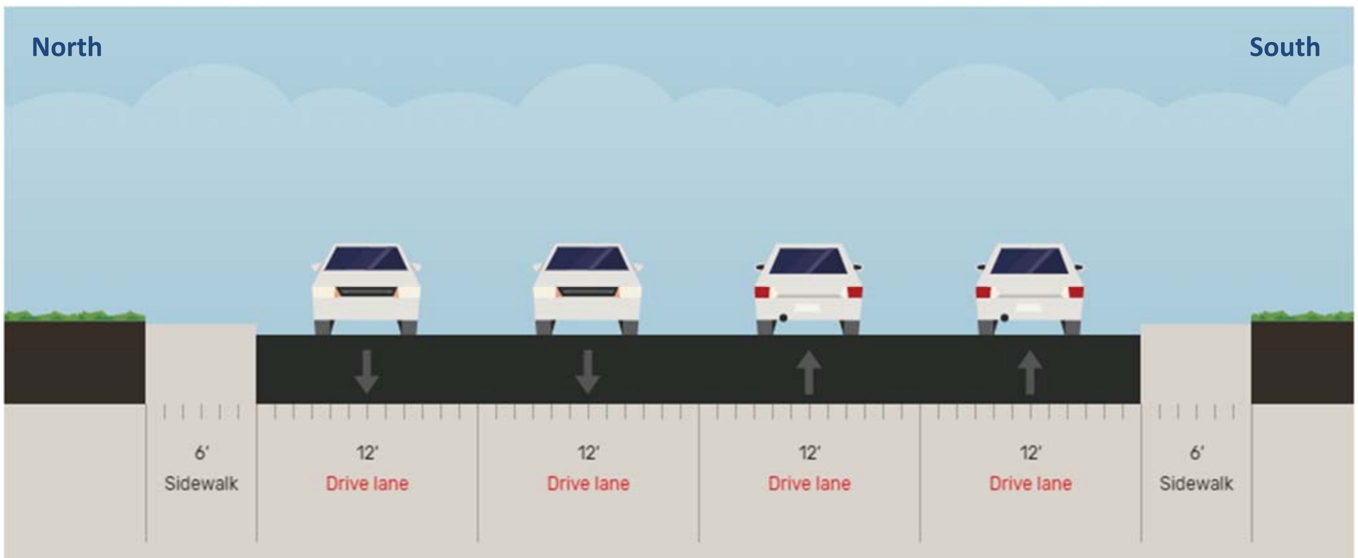

Figure 5: E Market Street Existing Cross Section

Crash Summary

The following crash summary was provided by city staff for inclusion in this memorandum. The data provided indicates that in the six years of data provided between 2016 and 2021, 13 crashes were recorded on the study segment of Garber's Church Road, 67 crashes were recorded on the study segment of W. Market Street and 110 crashes occurred on the study segment of E. Market Street. Rear end and angle collisions were the most frequent crash type on all three corridors. There were no fatalities recorded, and property damage only crashes were the most frequent severity with 67% of Garbers Church Road crashes, 72% of W. Market Crashes and 80% of E. Market Crashes. There was one pedestrian crash recorded each on E. Market Street and W. Market Street.

Garbers Church Road

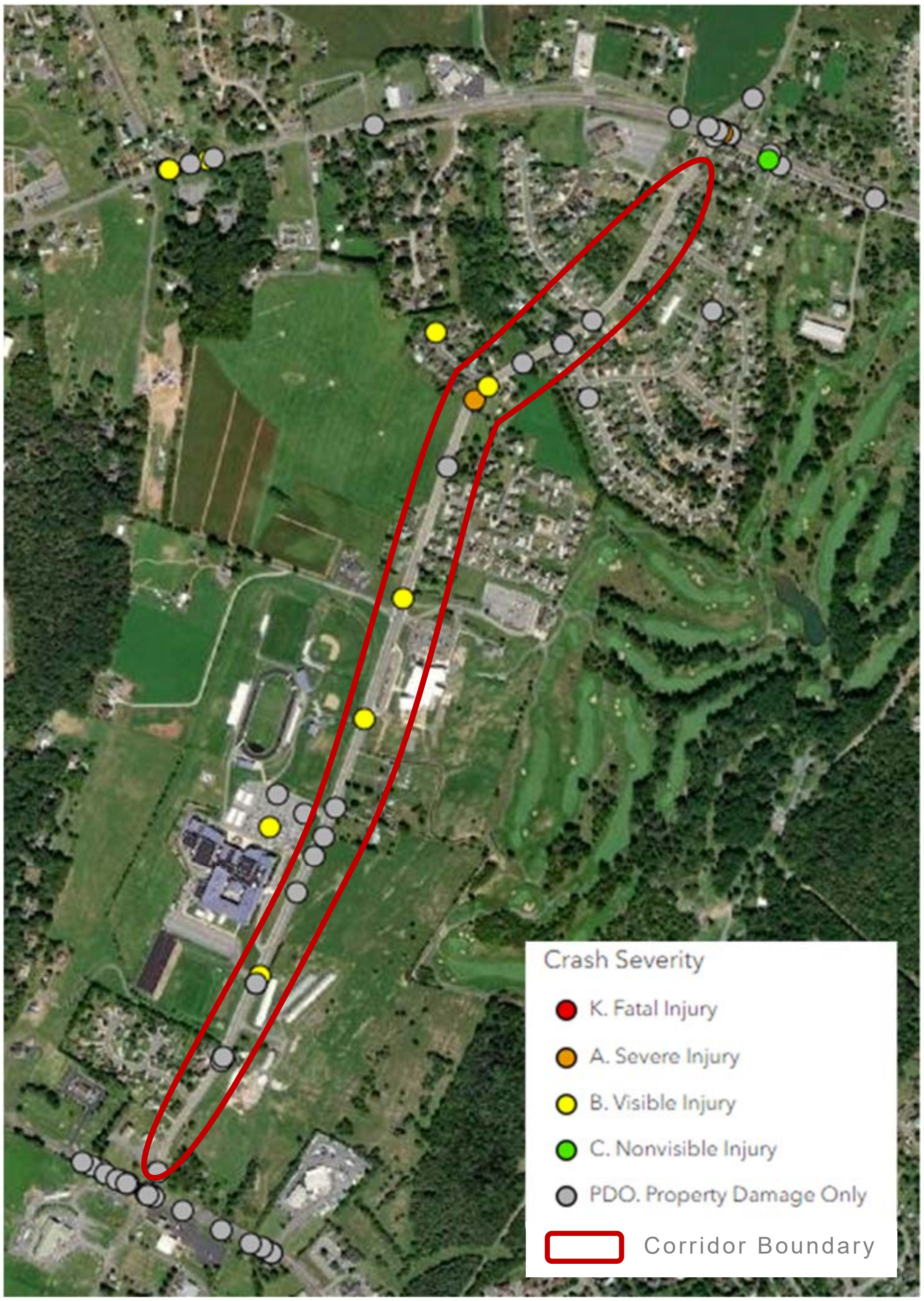

Figure 6: Garbers Church Road Crash Map

Table 4: Garbers Church Road Crash Summary – Collision Type

Year	Collision Type									Total
	Rear End	Angle	Head On	Side-swipe	Fixed Object in Road	Non-Collision	Fixed Object Off Road	Animal	Other	
2016	1	3								4
2017	1							1		2
2018		1						1	1	3
2019	1					1				2
2020										0
2021					1				1	2
Total	3	4	0	0	1	1	0	2	2	13
%	23%	31%	0%	0%	8%	8%	0%	15%	15%	

Table 5: Garbers Church Road Crash Summary – Crash Severity

Year	Crash Severity[1]					Total
	K	A	B	C	PDO	
2016			1		3	4
2017					2	2
2018			1		2	3
2019			1		1	2
2020						0
2021			1		1	2
Total	0	0	4	0	9	13
%	0%	0%	31%	0%	69%	

[1]Crash Severity definitions:
K = Fatal Injury, A = Severe Injury, B = Visible Injury, C = Nonvisible Injury, PDO = Property Damage Only

W Market Street

Figure 7: W Market Street Existing Crash Map

Table 6: W Market Street Crash Summary – Collision Type

Year	Collision Type									Total
	Rear End	Angle	Head On	Side-swipe	Fixed Object in Road	Non-Collision	Fixed Object Off Road	Animal	Other	
2016	6	5	1	1						13
2017	3	3		1				2		9
2018	7	7		2						16
2019	2	4	1	3					1*	11
2020	5	3		2					1	11
2021	1	5	1							7
Total	24	27	3	9	0	0	0	2	2	67
%	36%	40%	4%	13%	0%	0%	0%	3%	3%	

* = Pedestrian Crash

Table 7: W Market Street Crash Summary – Crash Severity

Year	Crash Severity[1]					Total
	K	A	B	C	PDO	
2016		1	4		8	13
2017			2		7	9
2018		1	4		11	16
2019		1	1	1	8	11
2020		1		1	9	11
2021		1		1	5	7
Total	0	5	11	3	48	67
%	0%	7%	16%	4%	72%	

[1]Crash Severity definitions:
K = Fatal Injury, A = Severe Injury, B = Visible Injury, C = Nonvisible Injury, PDO = Property Damage Only

E Market Street

Figure 8: E Market Street Existing Crash Map

Table 8: E Market Street Crash Summary – Collision Type

Year	Collision Type									Total
	Rear End	Angle	Head On	Side-swipe	Fixed Object in Road	Non-Collision	Fixed Object Off Road	Animal	Other	
2016	7	11					3		1*	22
2017	9	10	1	2			3			25
2018	7	14	1	1			2		1	26
2019	4	7					3			14
2020	3	2				2	3			10
2021	1	7	1		1		3			13
Total	31	51	3	3	1	2	17	0	2	110
%	28%	46%	3%	3%	1%	2%	15%	0%	2%	

* = Pedestrian Crash

Table 9: E Market Street Crash Summary – Crash Severity

Year	Crash Severity[1]					Total
	K	A	B	C	PDO	
2016		2		2	18	22
2017			5		20	25
2018			2		24	26
2019			4		10	14
2020			1	1	8	10
2021			2	2	9	13
Total	0	2	14	5	89	110
%	0%	2%	13%	5%	81%	

[1]Crash Severity definitions:
K = Fatal Injury, A = Severe Injury, B = Visible Injury, C = Nonvisible Injury, PDO = Property Damage Only

Roadway Reconfiguration Feasibility

FHWA Road Diet Informational Guide

ADT guidelines from the *FHWA Road Diet Informational Guide*[1] to determine the feasibility of a road diet are listed below:

- Less than 10,000 ADT: A great candidate for Road Diets in most instances. Capacity will most likely not be affected.
- 10,000-15,000 ADT: A good candidate for Road Diets in many instances. Agencies should conduct intersection analyses and consider signal retiming in conjunction with implementation.
- 15,000-20,000 ADT: A good candidate for Road Diets in some instances; however, capacity may be affected depending on conditions. Agencies should conduct a corridor analysis.
- Greater than 20,000 ADT: Agencies should complete a feasibility study to determine whether the location is a good candidate. Some agencies have had success with Road Diets at higher traffic volumes.

An assessment of the 2022 and projected 2040 ADT reveals that the study corridors are good or great candidates for road diets. According to the Guide, agencies should conduct intersection analyses and consider signal retiming in conjunction with implementation and should conduct a corridor analysis, which is described further in this memo.

[1] Knapp, Keith, et al. *Road diet informational guide.* No. FHWA-SA-14-028. United States. Federal Highway Administration. Office of Safety, 2014.

Roadway Reconfiguration Alternatives

As part of the corridor analyses, the project team developed three roadway reconfiguration alternatives for repurposing the available curb-to-curb space.

Garbers Church Road, W Market Street, and E Market Street are included in Harrisonburg's Bicycle & Pedestrian Plan as proposed pedestrian improvement segments, proposed shared use path, or proposed bike segments. The maps from this plan are shown in the figures below.

Based on these plans, the alternatives include bike facilities on each corridor.

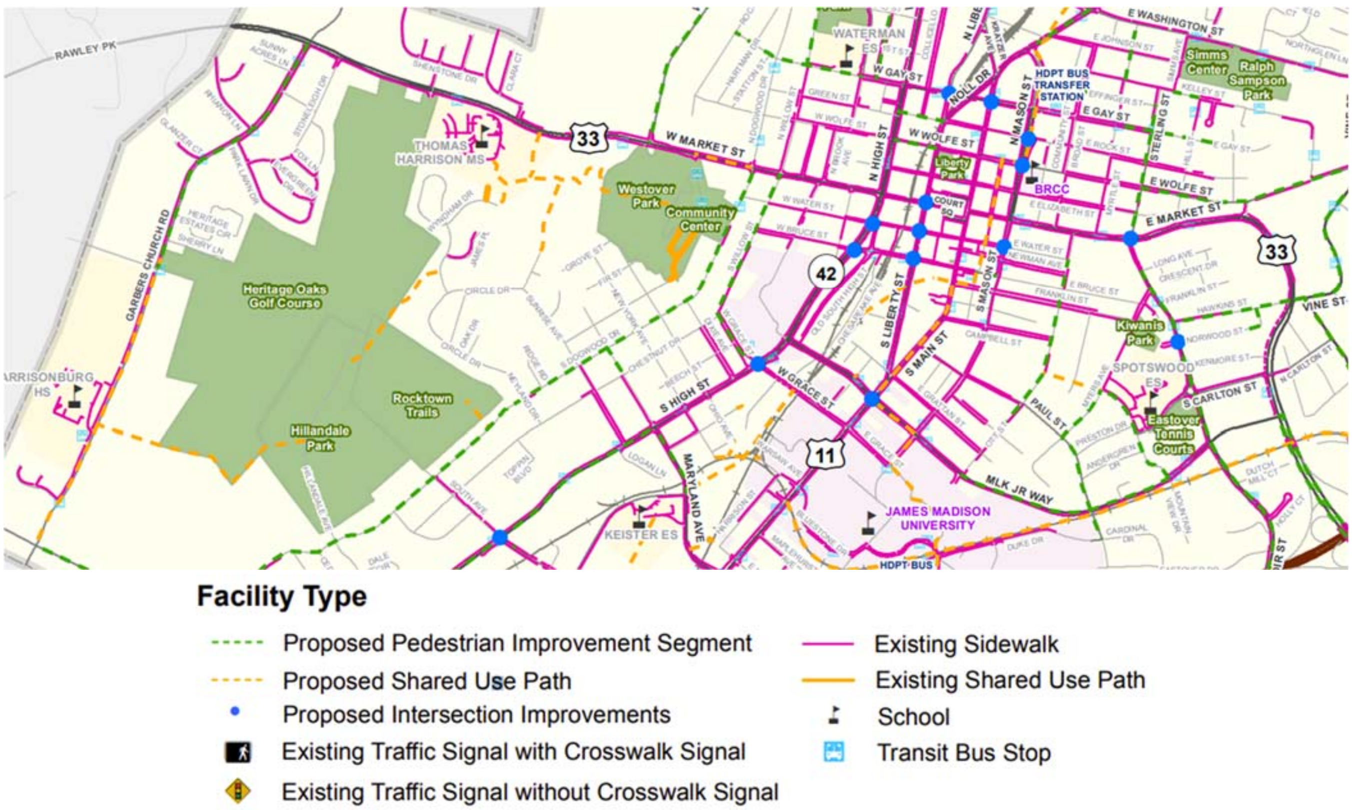

Figure 9: Proposed Pedestrian Facilities from the Harrisonburg Bicycle & Pedestrian Plan

Figure 10: Proposed Bicycle Facilities from the Harrisonburg Bicycle & Pedestrian Plan

The FHWA Bikeway Selection Guide [2], published in February 2019 was referenced to determine the preferred bikeway type based on speed and volume of the roadway. A figure from this guide for Urban, Urban Core, Suburban and Rural Town contexts is shown in the figure below.

Based on the speed and 2022 volumes on the study corridors, a separated bike lane or shared use path is the preferred bikeway type for all three segments.

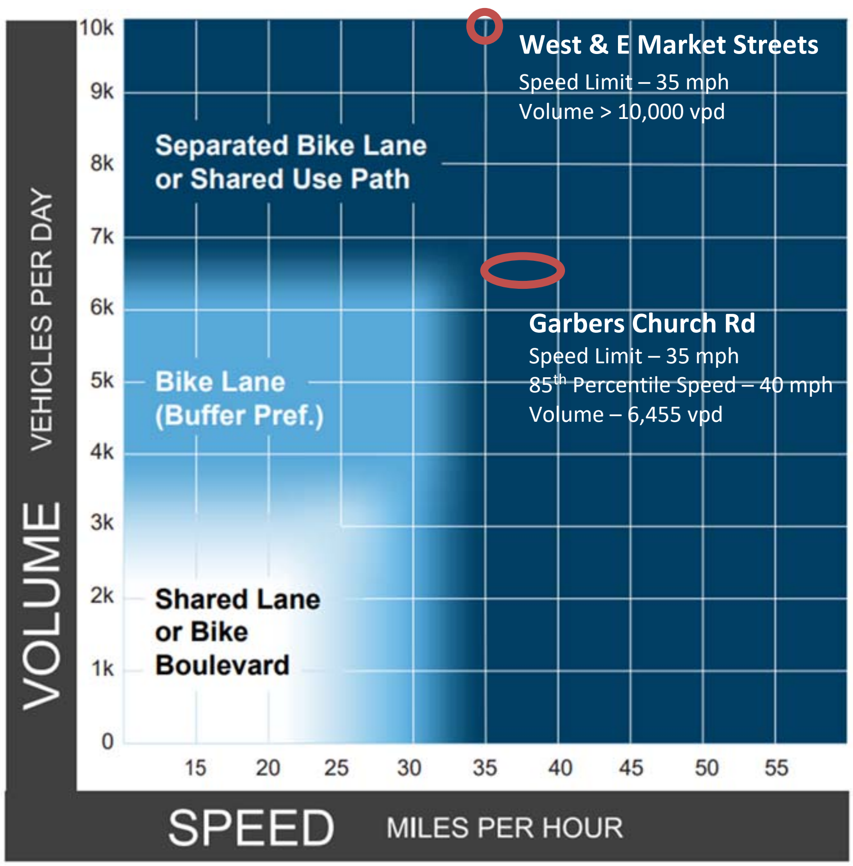

Figure 11: Preferred Bikeway Type for Urban, Urban Core, Suburban and Rural Town Contexts[2]

Note: 1. Chart assumes operating speeds are similar to posted speed.

2. Advisory bike lanes may be an option where traffic volume is <3K ADT.

[2] Schultheiss, Bill, et al. *Bikeway selection guide*. No. FHWA-SA-18-077. United States. Federal Highway Administration. Office of Safety, 2019.

Based on the preferred bikeway type from the FHWA Guide, the following three bike facility alternatives were developed. Dimensions and buffer materials presented in the figures in this section are illustrative and have been refined for the preferred alternative.

One-way separated bike lanes

- Separation can be curb or paint and bollards
- Median can be curb, painted, and/or provide turn lanes at intersections, or space can be allocated to bikeway and buffer depending on alignment and turn lane needs. Minimum pavement widths will be a consideration when choosing median type and width

Pros:

- Can maintain curbs, existing medians/turn lane locations
- Intuitive for users at intersections and driveways since cyclists would be traveling “with traffic”
- Cyclists in both directions can see both pedestrian and vehicular signal heads

Cons:

- Harder to transition to existing shared use paths
- More space must be dedicated to buffer on both sides of the roadway
- Requires careful design of buffer elements to provide a lower stress experience to cyclists

Figure 12: One-way Separated Bike Lanes Cross Section Example (Note: In most cases, the separation type would be the same on both sides of the street. This graphic shows a curbed planter strip on the left side and a paint-and-bollard design on the right side just to illustrate different options.)

Two-way separated bike lanes

- Separation can be curb or paint and bollards
- Median can be curb, painted, and/or provide turn lanes at intersections, minimum pavement widths will be a consideration when choosing median type and width

Pros:

- Can maintain curbs, existing medians/turn lane locations
- Easy transitions to existing shared use paths (Garber's Church) or potential future paths

Cons:

- Less intuitive conflicts at intersections and driveways with cyclists traveling "against" traffic.
- Requires visibility of crossing signals for counterflow cyclists (can use ped signal)
- More efficient use of buffer space
- Requires careful design of buffer elements to provide a lower stress experience to cyclists

Figure 13: Two-way Separated Bike Lane Cross Section Example

Shared-use path on one side

- Sidewalk level shared-use path (SUP)
- Median can be curb, painted, and/or provide turn lanes at intersections, minimum pavement widths will be a consideration when choosing median type and width

Pros:

- Easy transitions to existing shared use paths (Garber's Church) or potential future paths
- Most protected facility provides a very low stress experience to cyclists of all ages and abilities

Cons:

- Must relocate at least one side of curb and shift median, which increases implementation cost
- Requires visibility of crossing signals for counterflow cyclists (can use ped signal)
- More efficient use of buffer space
- Pedestrians and bicyclists use a shared space, which could create conflicts in the future if the volumes of people walking or biking grow significantly. Given present-day volumes of people walking and biking, it is unlikely that this is a concern.

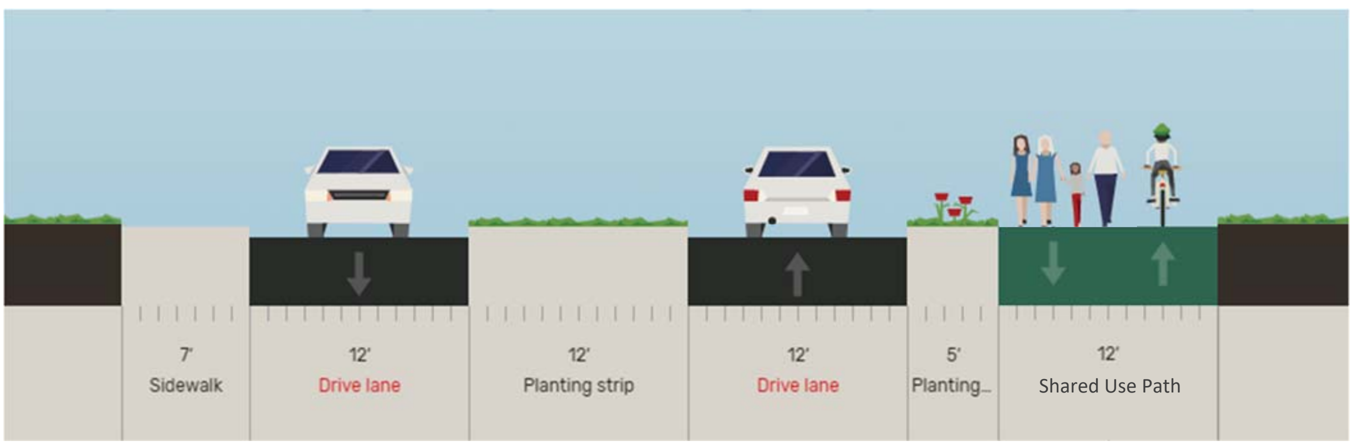

Figure 14: Shared-use Path Cross Section Example

Selection of Preferred Alternative

According to the City, the primary goal of the preferred alternative is to identify low-cost changes that can be completed with repaving of the roads. The repaving schedule is listed below. This will include primarily pavement marking, sign, and signal changes with the potential for addition of delineator posts (or similar) for protected bike lanes or intersection-specific physical changes such as installation of a pedestrian refuge island.

The estimated paving years for the corridors are:

- Garbers Church Road: 2023 for the segment between W Market St and the Bluestone Elementary School/Heritage Oaks Golf Course entrance; ~2027 for the remainder
- W Market Street: 2027-2030 for the whole corridor
- E Market Street: 2023

Based on the priority to maintain existing curb lines and limit impacts to signals, the preferred alternative for all three corridors under a road diet is one-way separated bike lanes that maintain the curbs. Concept designs have been developed for two alternative approaches. Each concept maintains one travel lane in each direction. Concept A includes turn lanes only where warranted as described later in this memorandum and reallocates that roadway space to provide a wider bike lane and buffer to maximize cyclist comfort and safety. Concept B maintains existing turn lanes at signalized intersections and provides a two-way center left-turn lane (TWLTL) through the majority of the corridor for turns at driveways and unsignalized intersections, which results in a minimum width of bike lane and buffer. In trade-off, Concept B allows for additional pedestrian crossing refuges at three-way intersections such as Broad Street or Ott Street at E. Market Street.

Traffic Operational Analysis

Traffic operational analysis was conducted at 26 intersections across the three corridors using Synchro analysis and HCM methodologies to determine the feasibility of removing a travel lane for roadway reconfiguration to accommodate the preferred alternative of one-way separated bike lanes that maintain the curbs. Traffic operational results, including vehicular delay, LOS, v/c, and 50th and 95th percentile queues, are presented for the AM and PM peak hours under future 2040 no build conditions and the preferred alternative with predicted 2040 traffic volumes. Details on the traffic operational analysis are provided below.

Study Intersections and Data Collection

The following intersections are included in the traffic operational analysis.

1. Garbers Church Rd and Erickson Ave (signalized) – via Gridsmart
2. Garbers Church Rd and HHS south entrance (signalized)
3. Garbers Church Rd and HHS inbound unsignalized loop entrance
4. Garbers Church Rd and HHS north entrance (signalized)
5. Garbers Church Rd and Bluestone ES inbound entrance
6. Garbers Church Rd and Heritage Center Way/Elementary School/Golf course
7. Garbers Church Rd and Heritage Estates
8. Garbers Church Rd and Park Lawn Dr
9. Garbers Church Rd and Rhianon Ln
10. Garbers Church Rd and Lendale Ln
11. Garbers Church Rd and W Market St (signalized)
12. W Market St and Stoneleigh Dr
13. W Market St and THMS/Westfield Ct (signalized)
14. W Market St and Brickstone Ct
15. W Market St and Waterman Dr (signalized)
16. W Market St and Dogwood Dr (signalized)
17. W Market St and Willow St
18. W Market St and High St (signalized) – via Gridsmart
19. E Market St and Mason St (signalized) – via Gridsmart
20. E Market St and Broad St
21. E Market St and Ott St
22. E Market St and Myrtle St
23. E Market St and Reservoir/Sterling (signalized)
24. E Market St and Hill St
25. E Market St and Old Furnace Rd
26. E Market St and Vine/Hawkins (signalized) – via Gridsmart

Peak period turning movement counts were collected in April 2022 from 7AM-9AM and 2PM-6PM or were provided by the City via the GridSmart system using the same day as the data collection for all study intersections. Based on the data collected, one AM and one PM peak hour was selected per corridor and the peak hour per corridor was used for analysis purposes. These peak hours are listed in the table below. Traffic count data is provided in Attachment A.

Table 10: Corridor Peak Hours

Corridor	AM Peak Hour	PM Peak Hour
Garbers Church Rd	7:00-8:00AM	3:00-4:00PM
W Market St	7:15-8:15AM	4:15-5:15PM
E Market St	7:45-8:45AM	4:15-5:15PM

Future 2040 volumes were calculated based on 2022 turning movement counts, a regional growth factor of 1% per year as provided by the City, and trip generation for one pending development project provided by the City. Details on land use and trip distribution for this development, as provided by the City is described below. The exiting trip distribution for the AM peak was modified in order to balance operations between the signalized and unsignalized intersections.

A proffered, rezoned development may add trips north of the W Market Street corridor with those trips entering the corridor at W Market Street & Westfield Ct and W Market Street & Brickstone Ct. That development is expected to be up to 350 single family residences. For this study, it is assumed that 1/3 of the trips will be allocated to W Market Street & Brickstone Ct and 2/3 to W Market Street & Westfield Ct. At the W Market Street & Brickstone Ct, it is assumed that all of the traffic will go to/from the downtown direction. At the W Market Street & Westfield Ct, the assumption is that 60% would go to/from the County (west) and the other 40% would go to/from the City.

The City provided signal timing sheets for all signalized intersections. Signal timings at some intersections were modified for the future no build conditions to accommodate the traffic growth.

Analysis Methodology

The traffic operational analysis methodology for motor vehicles is based on the concepts and procedures in the Highway Capacity Manual (HCM)[3] utilizing *Synchro 11* software. Results from HCM 6th Edition are reported if results were available for both the no build and preferred alternative conditions. HCM 2000 results are reported when HCM 6th Edition results were not available. The following measures were used to assess the impacts to vehicular travel:

[3] *Highway Capacity Manual 6th Edition, A Guide for Multimodal Mobility Analysis.* Transportation Research Board, National Research Council, Washington, DC 1207, 2016.

Volume-to-Capacity Ratio

Volume-to-capacity (v/c) ratio quantifies the degree to which a phase's capacity is utilized by a lane group at a signalized intersection.

Intersection Delay

Delay is the average amount of time, in seconds, that a vehicle takes to pass through an intersection beyond what would be experienced in a free-flow condition. Intersection delay is reported as overall vehicle delay and vehicle delay by movement for select locations with re-routed traffic.

Level of Service (LOS)

Vehicular Level of Service (LOS) is a qualitative measure of traffic congestion based on the average delay for a motorist. LOS is reported as overall intersection LOS and LOS by movement. LOS A represents minimum traffic delay and is an indication that there is underutilized roadway capacity during the peak hour. LOS F represents high levels of traffic delay. The table below, excerpted from the Highway Capacity Manual, provides LOS criteria for signalized and unsignalized intersections.

Table 11: Level of Service Relationship with Control Delay

Level of Service	Signalized Intersection Control Delay (seconds)	Unsignalized Intersection Control Delay (seconds)
A	0 to 10	0 to 10
B	> 10 to 20	> 10 to 15
C	> 20 to 35	> 15 to 25
D	> 35 to 55	> 25 to 35
E	> 55 to 80	> 35 to 50
F	> 80	> 50

50th and 95th Percentile Queues

The 95th-percentile queue is defined to be the queue length, in vehicles, that only has a 5% probability of being exceeded. It is a useful parameter for determining the appropriate length of turn pockets, but it is not typical of what an average driver would experience. The 50th-percentile queue is the queue length on a typical cycle.

Preferred Alternative Operational Details

Operational details for the preferred alternative including turn lane warrants and time-separated bicycle movement volume considerations. These details are summarized in the section below.

Turn Lanes

Turn lane warrants were evaluated based on the projected 2040 volumes of the higher peak hour for each corridor and the VDOT right- and left-turn lane warrants provided in Attachment B. The left-turn lane warrants are based on advancing volume, opposing volume, and percent left-turns. Right-turn lane warrants are based on the peak hour total approach volume and peak hour right turn volume. Tables 12 and 13 include details on existing turn lane locations, turn lane warrants, and the ultimate turn lane design included in the concept design. In some cases, a turn lane may not be warranted but was included because of the existing configuration. Turn lanes were shown to be warranted in two locations but were triggered by potential development volumes. The development project does not at this time include addition of turn lanes; therefore, turn lanes at these locations were not included in the concept design. These locations are noted with footnotes in the tables. In some locations existing turn lanes exist but are unwarranted and were removed from Concept A and that space was reallocated to provide wider bike lanes and additional buffer space. Existing turn lanes were maintained, or TWLTL was included through most of the corridor in Concept B regardless of warrant results.

Signal Operations

The concepts for the preferred alternative were developed assuming no changes to the existing signal infrastructure. Intersections were designed such that bicyclists could use the vehicle or pedestrian signals at signalized intersection. Conflict points and transitions at intersections are shown with design details to increase visibility and awareness for all users with green pavement markings.

Some locations with high volume of left or right-turning traffic would benefit from upgrades to the signal equipment that would provide an opportunity to include phase separation, such as protected-only left-turns or right-turn overlaps, to remove turning conflicts across the bike lanes. In order to provide this phase separation, left or right-turn lanes must also be provided. Locations that require signal phase changes that are possible with existing signal equipment, locations where there are space constraints that prevented the necessary turn lane for phase separated phasing, and locations that would require new signal equipment and therefore were not included in the models are noted with footnotes in Tables 12 and 13.

The Draft AASHTO Guide for the Development of Bicycle Facilities (Bike Guide) includes a table of volume considerations for time-separated bicycle movements, shown in the figure below. As primary authors of the forthcoming 5th Edition of the AASHTO's Bike Guide, Toole Design has included DRAFT design guidance from this unpublished document, but the same guidance is also available in the adopted MassDOT Separated Bike Lane Planning and Design Guide, as well as the adopted ODOT Multimodal Design Guide for reference. Movements that meet this threshold in at least one peak period were analyzed with separate phasing in the build Synchro models as a worst case scenario, as these phase separated movements would be a more impactful condition for motor vehicle operations.

Separated Bike Lane Operation	Motor Vehicles per Hour Turning across Separated Bike Lane			
	Two-way Street			One-way Street
	Right Turn	Left Turn across One Lane	Left Turn across Two Lanes	Right or Left Turn
One-way	150	100	50	150
Two-way	100	50	0	100

Figure 15: Volume Considerations for Time-separated Bicycle Movements (DRAFT AASHTO Bike Guide, MassDOT Separated Bike Lane Planning and Design Guide)

Table 12: Turn Lane warrants and phasing considerations by approach (Northbound/Eastbound)

Corridor (Peak used to check warrant)	Intersection	Control	Left	Through	Right	Advancing Volume	Opposing Volume	% Lefts	Existing left-turn lane	VDOT left-turn lane warrant for 2-lane highway	Concept A left-turn lane	Modeled left-turn lane	Existing left-turn phasing	Left-turn phasing considerations	Modeled left-turn phasing	Existing right-turn lane	VDOT right-turn lane warrant for 2-lane highway	Concept A right-turn lane	Modeled right-turn lane	Existing right-turn phasing	Right-turn phasing considerations	Modeled right-turn phasing
Garbers Church Rd – Northbound (AM Peak)	Erickson Ave	Signalized	23	78	35	136	102	17%	Yes	Not warranted	Yes	Yes	Protected-permitted	Concurrent	Protected-permitted	No	Not warranted	No	No	Permitted	Concurrent	Permitted
	HHS south entrance	Signalized	76	434	NA	510	337	15%	Yes	Warranted	Yes	Yes	Protected-permitted	Concurrent	Protected-permitted	NA	NA	NA	NA	NA	NA	NA
	HHS inbound loop	Unsignalized	97	355	NA	452	314	21%	Yes	Warranted	Yes	Yes	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	HHS north entrance	Signalized	186	274	0	460	320	40%	Yes	Warranted	Yes	Yes	Protected-permitted	Phase separate	Protected-only[2]	No	Not warranted	No	No	Permitted	Concurrent	Permitted
	Bluestone ES inbound	Unsignalized	NA	322	18	340	592	0%	NA	NA	NA	NA	NA	NA	NA	No	Not warranted	No	No	NA	NA	NA
	Heritage Center Way	Unsignalized	0	304	30	334	607	0%	Yes	Not warranted	No	No	NA	NA	NA	No	Not warranted	No	No	NA	NA	NA
	Heritage Estates	Unsignalized	NA	311	0	311	626	0%	NA	NA	NA	NA	NA	NA	NA	No	Not warranted	No	No	NA	NA	NA
	Park Lawn Dr	Unsignalized	NA	295	16	311	584	0%	NA	NA	NA	NA	NA	NA	NA	No	Not warranted	No	No	NA	NA	NA
	Rhianon Ln	Unsignalized	4	295	NA	299	574	1%	No	Not warranted	TWLTL	No	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Lendale Ln	Unsignalized	NA	288	8	296	542	0%	NA	NA	NA	NA	NA	NA	NA	No	Not warranted	No	No	NA	NA	NA
	W Market St	Signalized	18	60	270	348	157	5%	No	Not warranted	No	No	Split phased	Concurrent	Split phased	Yes	Warranted	Yes	Yes	Permitted	Phase separate	Overlap only[4]
W Market St – Eastbound (PM Peak)	Garbers Church Rd	Signalized	56	290	28	374	343	15%	Yes	Warranted	Yes	Yes	Protected-permitted	Concurrent	Protected-permitted	Yes	Not warranted	Yes	Yes	Permitted	Concurrent	Permitted
	Stoneleigh Dr	Unsignalized	NA	510	8	518	512	0%	NA	NA	NA	NA	NA	NA	NA	Yes	Not warranted	No	No	NA	NA	NA
	THMS/Westfield Ct[7]	Signalized	109	424	14	547	359	20%	Yes	Warranted	Yes	Yes	Protected-permitted	Phase separate	Protected-only[2]	Yes	Warranted[7]	Yes	Yes	Permitted	Concurrent	Permitted
	Brickstone Ct	Unsignalized	4	545	NA	549	586	1%	Yes	Warranted	Yes	Yes	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Waterman Dr	Signalized	100	476	0	576	728	17%	Yes	Warranted	Yes	Yes	Protected-permitted	Phase separate	Protected-only[2]	No	Not warranted	No	No	Permitted	Concurrent	Permitted
	Dogwood Dr	Signalized	19	532	92	643	653	3%	No	Warranted	Yes	Yes	Permitted	Concurrent	Permitted	No	Warranted	No	No	Permitted	Concurrent	Permitted
	Willow St	Unsignalized	11	566	11	588	648	2%	No	Warranted	Yes	Yes	NA	NA	NA	No	Not warranted	No	No	NA	NA	NA
	High St	Signalized	193	174	224	591	224	33%	Yes	Warranted	Yes	Yes	Protected-permitted	Phase separate	Protected-permitted[6]	No	Warranted	No	No	Permitted	Phase separate[3]	Permitted
E Market St – Eastbound (PM Peak)	Mason St	Signalized	NA	240	26	266	242	0%	NA	NA	NA	NA	NA	NA	NA	No	Not warranted	No	No	Permitted	Concurrent	Permitted
	Broad St	Unsignalized	13	726	NA	739	756	2%	No	Warranted	TWLTL	Yes	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Ott St	Unsignalized	NA	791	4	795	800	0%	NA	NA	NA	NA	NA	NA	NA	No	Not warranted	No	No	NA	NA	NA
	Myrtle St	Unsignalized	17	865	NA	882	814	2%	No	Warranted	TWLTL	Yes	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Reservoir/Sterling	Signalized	1	607	252	860	500	0%	No	Not warranted	No	No	Permitted	Concurrent	Permitted	No	Warranted	Yes	Yes	Permitted	Phase separate	Overlap only[4]
	Hill St	Unsignalized	6	666	NA	672	520	1%	No	Warranted	TWLTL	Yes	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Old Furnace Rd	Unsignalized	127	620	NA	747	482	17%	Yes	Warranted	Yes	Yes	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Vine/Hawkins[1]	Signalized	6	542	97	645	524	1%	Yes	Warranted	Yes	Yes	Protected-permitted	Concurrent	`	No	Warranted	No	No	Permitted	Concurrent	Permitted

1 - Warrants were checked but concept ends before intersection
2 - Requires phasing changes - possible with existing signal equipment
3 - Not incorporated - space constraints
4 - Requires phasing changes - new signal equipment needed (location of bike lane would change in concept if this option is implemented)
5 - NTOR recommended with mixing zone layout
6 - Concept ends at intersection; Phase separation should be considered if it is desired to accommodate bike facilities through the intersection.
7 - Warrants also checked with AM Peak volumes because of school traffic

Table 13: Turn Lane warrants and phasing considerations by approach (Southbound/Westbound)

Corridor (Peak used to check warrant)	Intersection	Control	Left	Through	Right	Advancing Volume	Opposing Volume	% Lefts	Existing left-turn lane	VDOT left-turn lane warrant for 2-lane highway	Concept A left-turn lane	Modeled left-turn lane	Existing left-turn phasing	Left-turn phasing considerations	Modeled left-turn phasing	Existing right-turn lane	VDOT right-turn lane warrant for 2-lane highway	Concept A right-turn lane	Modeled right-turn lane	Existing right-turn phasing	Right-turn phasing considerations	Modeled right-turn phasing
Garbers Church Rd – Southbound (AM Peak)	Erickson Ave	Signalized	289	102	4	395	78	73%	Yes	Not warranted	Yes	Yes	Protected-permitted	Phase separate	Protected-permitted[6]	No	Not warranted	No	No	Permitted	Concurrent	Permitted
	HHS south entrance	Signalized	NA	337	42	379	434	0%	NA	NA	NA	NA	NA	NA	NA	No	Not warranted	No	No	Permitted	Concurrent	Permitted
	HHS inbound loop	Unsignalized	NA	314	65	379	355	0%	NA	NA	NA	NA	NA	NA	NA	No	Not warranted	No	No	NA	NA	NA
	HHS north entrance	Signalized	0	320	304	624	274	0%	Yes	Not warranted	No	No	Permitted	Concurrent	Permitted	No	Warranted	Yes	Yes	Permitted	Phase separate[3]	Permitted
	Bluestone ES inbound	Unsignalized	23	592	NA	615	322	4%	No	Warranted	Yes	Yes	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Heritage Center Way	Unsignalized	26	607	0	633	304	4%	Yes	Warranted	Yes	Yes	NA	NA	NA	No	Not warranted	No	No	NA	NA	NA
	Heritage Estates	Unsignalized	0	626	NA	626	311	0%	No	Not warranted	TWLTL	No	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Park Lawn Dr	Unsignalized	1	584	NA	585	295	0%	No	Not warranted	TWLTL	No	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Rhianon Ln	Unsignalized	NA	574	5	579	295	0%	NA	NA	NA	NA	NA	NA	NA	No	Not warranted	No	No	NA	NA	NA
	Lendale Ln	Unsignalized	0	542	NA	542	288	0%	No	Not warranted	TWLTL	No	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	W Market St	Signalized	24	157	50	231	60	10%	No	Not warranted	No	No	Split phased	Concurrent	Split phased	Yes	Not warranted	Yes	Yes	Permitted	Concurrent	Permitted
W Market St – Westbound (PM Peak)	Garbers Church Rd	Signalized	144	343	26	513	290	28%	Yes	Warranted	Yes	Yes	Protected-only	Phase separate	Protected-only	Yes	Not warranted	Yes	Yes	Permitted	Concurrent	Permitted
	Stoneleigh Dr	Unsignalized	43	512	NA	555	510	8%	Yes	Warranted	Yes	Yes	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	THMS/Westfield Ct	Signalized	31	359	82	472	424	7%	Yes	Warranted	Yes	Yes	Protected-permitted	Phase separate	Protected-only[2]	No	Warranted with development	No	No	Permitted	Concurrent	Permitted
	Brickstone Ct	Unsignalized	NA	586	112	698	545	0%	Yes	NA	Yes	NA	NA	NA	NA	No	Warranted with development	No	No	NA	NA	NA
	Waterman Dr	Signalized	0	728	102	830	476	0%	No	Not warranted	No	No	Permitted	Concurrent	Permitted	Yes	Warranted	Yes	Yes	Permitted	Concurrent	Permitted
	Dogwood Dr	Signalized	24	653	12	689	532	3%	No	Warranted	Yes	Yes	Permitted	Concurrent	Permitted	No	Not warranted	No	No	Permitted	Concurrent	Permitted
	Willow St	Unsignalized	23	648	8	679	566	3%	No	Warranted	Yes	Yes	NA	NA	NA	No	Not warranted	No	No	NA	NA	NA
	High St	Signalized	71	224	12	307	174	23%	Yes	Warranted	Yes	Yes	Protected-permitted	Concurrent	Protected-permitted	No	Not warranted	No	No	Permitted	Concurrent	Permitted
E Market St – Westbound (PM Peak)	Mason St	Signalized	193	242	305	740	240	26%	Yes	Warranted	Yes	Yes	Protected-permitted	Phase separate	Protected-permitted[6]	No	Warranted	Yes	Yes	Permitted	Phase separate[3]	Permitted + NTOR[5]
	Broad St	Unsignalized	NA	756	47	803	726	0%	NA	NA	NA	NA	NA	NA	NA	No	Warranted	No	No	NA	NA	NA
	Ott St	Unsignalized	28	800	NA	828	791	3%	No	Warranted	TWLTL	Yes	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Myrtle St	Unsignalized	NA	814	14	828	865	0%	NA	NA	NA	NA	NA	NA	NA	No	Not warranted	No	No	NA	NA	NA
	Reservoir/Sterling	Signalized	2	500	13	515	607	0%	No	No	No	No	Permitted	NA	Permitted	No	Not warranted	No	No	Permitted	Concurrent	Permitted
	Hill St	Unsignalized	NA	520	28	548	666	0%	NA	NA	NA	NA	NA	NA	NA	No	Not warranted	No	No	NA	NA	NA
	Old Furnace Rd	Unsignalized	NA	482	134	616	620	0%	NA	NA	NA	NA	NA	NA	NA	Yes	Warranted	Yes	Yes	NA	NA	NA
	Vine/Hawkins[1]	Signalized	25	524	284	833	542	3%	Yes	Warranted	Yes	Yes	Protected-permitted	Concurrent	Protected-permitted	Yes	Warranted	Yes	Yes	Permitted	Phase separate	Permitted

1 - Warrants were checked but concept ends before intersection
2 - Requires phasing changes - possible with existing signal equipment
3 - Not incorporated - space constraints
4 - Requires phasing changes - new signal equipment needed (location of bike lane would change in concept if this option is implemented)
5 - NTOR recommended with mixing zone layout
6 - Concept ends at intersection; Phase separation should be considered if it is desired to accommodate bike facilities through the intersection.
7 - Warrants also checked with AM Peak volumes because of school traffic

Analysis Results

Overall intersection analysis results are provided in Table 8. Detailed results by movement and Synchro reports are provided in Attachment C.

As shown in the overall intersection analysis results, all signalized intersections would operate at an overall intersection LOS of D or better, with the exception of E. Market Street at Vine Street, which is projected to operate at LOS E in both the Build and No-Build Alternative. Based on the projected future traffic volumes, which include 1% growth per year to 2040, and roadway reconfiguration alternatives, in the PM peak the northbound approach of West Market St and Willow St, and the southbound approaches of East Market St and Broad St and East Market St and Old Furnace Rd would operate at LOS F. In the AM peak the eastbound right-turn movement at East Market St and Reservoir/Sterling would operate at LOS F. Based on this analysis the **roadway reconfiguration is feasible**, with some potential mitigations needed at specific approach locations if future growth is realized.

Table 14: Overall intersection analysis results

Corridor	Intersection	Control	Reporting	AM No Build		AM Alternative		PM No Build		PM Alternative	
				Delay (sec)	LOS	Delay (sec)	LOS	Delay (sec)	LOS	Delay (sec)	LOS
Garbers Church Rd	Erickson Ave	Signalized	HCM6	35.9	D	36.0	D	42.4	D	42.4	D
	HHS south entrance	Signalized	HCM2000	6.3	A	7.7	A	6.4	A	7.3	A
	HHS inbound loop	Unsignalized	HCM2000	1.0	A	1.0	A	0.1	A	0.1	A
	HHS north entrance	Signalized	HCM6	11.9	B	19.3	B	9.8	A	12.4	B
	Bluestone ES inbound	Unsignalized	HCM2000	0.2	A	0.2	A	0.1	A	0.1	A
	Heritage Center Way	Unsignalized	HCM6	0.3	A	0.3	A	2.4	A	2.8	A
	Heritage Estates	Unsignalized	HCM6	0.0	NA	0.1	A	0.2	A	0.2	A
	Park Lawn Dr	Unsignalized	HCM6	0.7	A	1.0	A	0.4	A	0.5	A
	Rhianon Ln	Unsignalized	HCM6	0.4	A	0.5	A	0.4	A	0.4	A
	Lendale Ln	Unsignalized	HCM6	0.5	A	0.6	A	0.2	A	0.2	A
	W Market St[1]	Signalized	HCM2000			46.3	D			31.9	C
Garbers Church Rd & W Market Street[2]		Signalized	HCM2000	42.3	D	48.4	D	30.5	C	34.6	C
W Market St	Garbers Church Rd[3]	Signalized	HCM2000			49.0	D			34.0	C
	Stoneleigh Dr	Unsignalized	HCM6	0.8	A	0.9	A	0.7	A	0.8	A
	THMS/Westfield Ct	Signalized	HCM6	20.7	C	51.3	D	14.2	B	33.3	C
	Brickstone Ct	Unsignalized	HCM6	2.4	A	1.6	A	1.4	A	1.9	A
	Waterman Dr	Signalized	HCM6	12.5	B	19.7	B	14.4	B	27.4	C
	Dogwood Dr	Signalized	HCM6	8.7	A	12.9	B	8.6	A	13.0	B
	Willow St	Unsignalized	HCM6	1.5	A	1.7	A	2.9	0.0	3.4	A
	High St	Signalized	HCM6	45.9	D	45.9	D	51.5	D	51.5	D
E Market St	Mason St	Signalized	HCM6	16.2	B	16.0	B	34.2	C	32.6	C
	Broad St	Unsignalized	HCM6	0.5	A	0.6	A	1.8	A	3.2	A
	Ott St	Unsignalized	HCM6	0.7	A	0.6	A	1.2	A	1.5	A
	Myrtle St	Unsignalized	HCM6	0.4	A	0.4	A	0.4	A	0.4	A
	Reservoir/Sterling	Signalized	HCM2000	19.5	B	28.4	C	33.3	C	42.5	D
	Hill St	Unsignalized	HCM6	0.5	A	0.6	A	1.3	A	2.0	A
	Old Furnace Rd	Unsignalized	HCM6	2.3	A	2.8	A	5.6	A	12.4	B
	Vine/Hawkins	Signalized	HCM2000	47.8	D	47.8	D	64.1	E	64.1	E

1 – Road reconfiguration on Garbers Church Rd only
2 – Both roads reconfigured
3 - Road reconfiguration on W Market St only

Concept Design Details

The following section includes design details included in the concept designs developed for potential roadway reallocation.

Lane Widths

Motor Vehicle Lane

The City has generally used 11 foot vehicle lane widths with recent roadway designs. Vehicle lane widths of 11 feet were generally used in both concepts. In locations on each concept where a two-way center left-turn lane is included, if ROW is constrained the TWLTL was reduced to 10 feet as needed to maintain minimum widths for the bicycle lanes and buffers.

Bike Lanes

A one-way separated bike lane width of 8 feet was generally used throughout Concept A, measured from the face of curb. This width allows for the physical space associated with side-by-side riding, shy distance from gutter/curb, vertical elements in the buffer, or another without creating confusion with a vehicular lane or parking lane. In Concept B, in order to maintain space for a TWLTL or other turn lanes, the bike lane was reduced to a minimum 6 foot from face of curb, which provides the minimum 5 foot of useable width for the bike lane exclusive of the gutter. VDOT's Road Design Manual allows for a minimum 4 feet of rideable space; however, this does not provide sufficient operating space for the typical rider to feel comfortable.

Buffer Width

The buffer width varies based on available right-of-way. Concept A generally includes a 6 foot minimum buffer, and Concept B includes a minimum 2 foot buffer. In both concepts there are limited pinch points where the buffer is reduced below those minimums or removed entirely; however, generally a consistent width should be provided and only reduced in short sections where necessary based on constraints of the existing curbs. A two foot buffer is the minimum necessary to be able to provide vertical elements in the buffer; however, particularly where vehicular speeds exceed 30 mph, a wider buffer is desirable.

Protected Intersections and Crossing Offsets

The six foot buffer shown in Concept A allows for provision of an offset between the adjacent vehicular lane and the bike lane. The DRAFT 2022 AASHTO Bike Guide, as well as the MassDOT Separated Bike Lane Guide indicate that a desirable bicycle crossing is offset is 6 feet to 16.5 feet from the adjacent travel lane. These offsets have been found to reduce conflicts between turning motorists and bicyclists by 50%. At all crossing locations, and particularly uncontrolled crossing locations, the bike lane has been shown as slightly bent away from the adjacent travel lane approaching the crossing to maximize this offset within the desired dimensions. This provides space for right-turning vehicles to see, react to and yield to cyclists before completing their turn maneuver.

There are several locations in Concept A where the removal of an existing unwarranted turn lane provides additional roadway space. At those locations, the additional buffer space provided could be used to provide protected intersection elements. Protected intersections maintain separation of bicyclists throughout the intersection. The continued separation of modes reduces potential conflicts and clarifies right-of-way. Design elements of these intersections are shown in Figure 16 and include (1) a corner refuge island with a small curb radius, (2) a motorist yield zone, (3) bicycle queuing areas, and (4) marked pedestrian crossings of the roadway and bicycle lane. Protected intersections make bicyclists and pedestrians more visible to motorists and provide physical space for motorists to yield to vulnerable users as they turn.

Figure 16: Design Elements of a Protected Intersection. Design elements include (1) a corner refuge island with a small curb radius, (2) a motorist yield zone, (3) bicycle queuing areas, and (4) marked pedestrian crossings.

Buffer Material

The concepts show hatching through the buffer zones. In order to provide more comfortable facilities for cyclists and positive guidance for drivers, vertical elements should be provided in the buffer, particularly at intersection approaches or other strategic locations where drivers are likely to attempt to drive in the buffer space. Several buffer options from the FHWA Separated Bike Lane Planning and Design Guide are listed below and more detail is provided in Attachment D.

- Delineator Posts
- Bollards
- Raised Median
- Planters
- Parking Stops

Design Guidance

The design elements included in the concepts rely on the following design guidance:

- DRAFT 2022 AASHTO Bike Guide (see MassDOT Separated Bike Guide or ODOT Multimodal Design Guide for similar published guidance of some elements)
- FHWA Bikeway Selection Guide
- VDOT Road Design Manual

Next Steps

In order to advance these concepts to final design additional information including topographic survey, signal modification design, and AutoTurn design vehicle turn movement analysis would be required. With additional information design advancement may identify locations where the minimum widths shown cannot be accommodated within the existing curbs or other modifications are needed to the elements shown.